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**NATIONWIDE INVENTORY
OF AIR POLLUTANT EMISSIONS
1968**

**U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service**

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National Air Pollution Control Administration
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PREFACE

The National Air Pollution Control Administration (NAPCA) has gathered comprehensive data, summarized in this report, on the emission of air pollutants in the United States. The data presented are the estimates of the 1968 nationwide emissions of the five primary air pollutants: carbon monoxide (CO), sulfur oxides (SO_x), particulates, hydrocarbons (HC), and nitrogen oxides (NO_x). Emission trends from 1966 through 1968 are included as well as motor vehicle emissions projected to 1990.

Because of the increasing availability of more comprehensive data and emission factors, revisions will be made in emission quantities in the future. Consequently, the numbers given in this document are subject to change.

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NATIONWIDE INVENTORY OF AIR POLLUTANT EMISSIONS, 1968

INTRODUCTION

This report summarizes the estimates for 1968 of nationwide emissions of the five primary air pollutants, with information on nationwide emissions given by source category and location (urban and non-urban). Information on emission trends from 1966 to 1968 is included as well as projections of motor vehicle emissions to the year 1990 for HC, CO, and NO_x. Presented also are the methodology and basic data used to make the emission estimates, such as fuel usage, vehicle miles of travel, and solid waste disposal methods. A more detailed presentation of nationwide emission estimates, together with a description of estimating techniques, is included in the data file that serves as NAPCA's reference source with respect to nationwide emission estimates.

The nationwide estimates in this document are for the year 1968. More recent estimates are difficult to develop since many of the basic data are not available for a more current year. Data for 1968 should, however, provide the basis for an adequate estimate of present conditions.

The accuracy of the estimates given for the pollutants varies. Detailed studies have been completed for three of the five primary pollutants: CO, SO_x, and NO_x. Estimates for these pollutants should be accurate. For the others, estimates may be inaccurate because of the lack of emission factors and basic source information. In addition, information on the extent and degree of control exercised over particulate emissions in several categories is not yet adequate.

For the purposes of presenting and comparing nationwide emissions, 1966 was picked as the base year so that deviations in emissions

from one year to another are compared to those occurring in 1966.

Two basic differences can occur in emission rates from year to year. The first is an actual change based on increases (or decreases) in fuel usage, industrial production, population, vehicular travel, or refuse disposal rates. The second type, an apparent change, consists of actual changes combined with changes in emission factors or the inclusion of new sources. Thus a source category may appear to show a decrease in emissions when actually the emissions are the same and only the emission factor used to convert the basic data into emission data was revised. Or, a category's emission rate can jump drastically because of the inclusion of a source that was not previously considered.

Refinements in estimating techniques, development of new emission factors, actual changes in pollutant emissions, and the introduction and improvement of controls will necessitate frequent revisions of pollutant estimates. Present plans call for updating the reference data annually.

NATIONWIDE EMISSIONS

Nationwide emission estimates for the year 1968 are presented in Table 1. The totals are for the most part higher than previous NAPCA estimates, primarily because of the inclusion of sources not previously considered. For example, emission estimates have been included for forest fires, burning of coal refuse banks, and an increased number of industrial process sources. The numbers presented here should be representative of current emissions.

Table 1. ESTIMATED NATIONWIDE EMISSIONS, 1968
(10⁶ tons/year)

Source	CO	Particulates	SO _x ^a	HC	NO _x ^b
Transportation	63.8	1.2	0.8	16.6	8.1
Fuel combustion in stationary sources	1.9	8.9	24.4	0.7	10.0
Industrial processes	9.7	7.5	7.3	4.6	0.2
Solid waste disposal	7.8	1.1	0.1	1.6	0.6
Miscellaneous	16.9	9.6	0.6	8.5	1.7
Total	100.1	28.3	33.2	32.0	20.6

^aSO_x expressed as SO₂ throughout this summary.

^bNO_x expressed as NO₂ throughout this summary.

CARBON MONOXIDE

In 1968, approximately 100 million tons of carbon monoxide (Table 2) was emitted in the United States. The amount will be lower in 1970, largely because the use of controls on vehicle exhausts will counteract any increases in emissions of CO from other sources.

Gasoline-powered motor vehicles are the largest single emitters of CO and account for 59 million tons per year, or 59 percent of the total. The next largest source category includes forest fires, structural fires, agricultural burning, and the burning of coal refuse banks, which

collectively emit about 17 million tons per year. (This is an extremely rough approximation.) Industrial sources emit almost 10 million tons of CO, a large majority of it from foundries, petroleum refineries, sintering, and kraft paper mills. Solid waste disposal, stationary fuel combustion, and transportation sources other than automobiles account for the remaining 14 million tons.

Table 2. NATIONWIDE CARBON MONOXIDE EMISSIONS, 1968

Source	Emissions, 10 ⁶ tons/yr	Percent of total
Transportation	63.8	63.8
Motor vehicles	59.2	59.2
Gasoline	59.0	59.0
Diesel	0.2	0.2
Aircraft	2.4	2.4
Railroads	0.1	0.1
Vessels	0.3	0.3
Non-highway use of motor fuels	1.8	1.8
Fuel combustion in stationary sources	1.9	1.9
Coal	0.8	0.8
Fuel oil	0.1	0.1
Natural gas	N ^a	N
Wood	1.0	1.0
Industrial processes	9.7	9.6
Solid waste disposal	7.8	7.8
Miscellaneous	16.9	16.9
Forest fires	7.2	7.2
Structural fires	0.2	0.2
Coal refuse burning	1.2	1.2
Agricultural burning	8.3	8.3
Total	100.1	100.0

^aN = Negligible.

The estimated 60 million tons (60 percent of the national total) emitted in urban areas is largely from motor vehicle exhaust. Even though vehicular travel is evenly divided between urban and rural areas, traffic in urban areas, where slower driving speeds prevail, accounts for 70 percent of total motor vehicle emissions of CO. In addition, essentially all of the aircraft emissions (at altitudes below 3,000 feet), industrial emissions, and the majority of emissions from fuel combustion

and refuse disposal occur in urban areas.

In 1966, 101.6 million tons of carbon monoxide was emitted in the United States. Emissions decreased to 100.1 million tons in 1968 as a result of the following changes in source categories:

1. A 1.4-million-ton actual decrease in motor vehicle emissions due to Federal emission exhaust standards.
2. A 1.0-million-ton overall decrease in industrial process emissions. This was due to changes in emission factors for pulp and paper and increases from other industries such as grey-iron foundries and oil refineries. This is an apparent decrease only, since emissions from this category actually increased. If the new emission factors are applied to the 1966 data, the actual change from 1966 to 1968 was an increase of 0.9 million tons.
3. A 0.2-million-ton actual increase in emissions from solid waste disposal.
4. A 0.7-million-ton actual increase from uncontrolled transportation sources such as aircraft, diesel-powered motor vehicles, and the off-highway use of motor fuels.

Table 3 shows changes in CO emission rates by source category for the years 1966 through 1968. An apparent decrease in emissions occurred in the industrial process category, as shown in the table, although the actual rate increased. This was due to changes made in emission factors used for the 1967 estimates.

PARTICULATES

The accurate estimation of nationwide particulate pollution is extremely difficult because many particulate emissions, unlike gaseous emissions, are under some sort of control. The extent and efficiency of these controls have not been evaluated nationally. In addition, emissions from many activities have not been quantified. The following estimates should be viewed with these limitations in mind.

Table 3. NATIONWIDE EMISSIONS OF CARBON MONOXIDE BY YEAR
(10⁶ tons)

Source	1966	1967	1968	Change from 1966 to 1968
Transportation	64.5	65.0	63.8	-0.7
Motor vehicles	60.6	61.2	59.2	-1.4
Other	3.9	3.8	4.6	+0.7
Fuel combustion	1.9	1.9	1.9	N ^a
Coal	0.9	0.9	0.8	-0.1
Fuel oil	N	N	0.1	+0.1
Natural gas	N	N	N	N
Wood	1.0	1.0	1.0	N
Industrial processes	10.7	9.5	9.7	-1.0 ^b
Solid waste disposal	7.6	7.8	7.8	+0.2
Miscellaneous	16.9	16.9	16.9	N
Man-made	9.7	9.7	9.7	N
Forest fires	7.2	7.2	7.2	N
Total	101.6	101.1	100.1	-1.5

^aN = Negligible.

^bApparent change.

A rough estimate places the national emissions of particulates at about 28.3 million tons for 1968 (Table 4). Besides the 6.7 million tons attributed to forest fires, 21.6 million tons was emitted by combustion, transportation, and industrial process sources.

Total emissions from fuel combustion in stationary sources are estimated to have been over 8.9 million tons for 1968. Power plants and industries emitted 5.6 million tons and 2.6 million tons, respectively. The burning of coal accounted for 92 percent, or 8.2 million tons, of fuel combustion emissions.

Although complete data are not available, industrial process sources are estimated to have accounted for the emission of 7.5 million tons of particulates. (Table 5 presents a detailed breakdown of particulate emissions from industrial processes.) Iron and steel mill complexes comprised the largest source in this category, collectively generating some 1.9 million tons of particulate matter annually. The sand, stone, and rock industries and cement plants, the next largest sources, each emitted 870 thousand tons.

Table 4. NATIONWIDE EMISSIONS OF PARTICULATES, 1968

Source	Emissions, 10 ⁶ tons/yr	Percent of total
Transportation	1.2	4.3
Motor vehicles	0.8	2.8
Gasoline	0.5	1.8
Diesel	0.3	1.0
Aircraft	N ^a	N
Railroads	0.2	0.7
Vessels	0.1	0.4
Non-highway use of motor fuels	0.1	0.4
Fuel combustion in stationary sources	8.9	31.4
Coal	8.2	29.0
Fuel oil	0.3	1.0
Natural gas	0.2	0.7
Wood	0.2	0.7
Industrial processes	7.5	26.5
Solid waste disposal	1.1	3.9
Miscellaneous	9.6	33.9
Forest fires	6.7	23.7
Structural fires	0.1	0.4
Coal refuse burning	0.4	1.4
Agricultural burning	2.4	8.4
Total	28.3	100.0

^aN = Negligible.

Table 5. PARTICULATE EMISSIONS FROM INDUSTRIAL PROCESSES, 1968
(tons/year)

Industry	Emissions
Iron and steel	1,910,000
Other primary metals	40,000
Grey-iron foundries	170,000
Other secondary metals	50,000
Cement	870,000
Stone, sand, rock, etc.	870,000
Coal cleaning	185,000
Phosphate rock	205,000
Lime	450,000
Asphalt batching	540,000
Other mineral products	180,000
Oil refineries	100,000
Other chemical industries	90,000
Grain handling and storage	800,000
Pulp and paper	720,000
Flour and feed milling	320,000
Other	30,000

Transportation and solid waste disposal accounted for the remaining 2.3 million tons.

Estimates of particulate emissions in highly industrialized urban areas range from 200,000 to 600,000 tons per year.

Among these areas are Chicago (600,000 tons), Pittsburgh (400,000 tons), and Philadelphia (200,000 tons). On the other hand, several heavily populated metropolitan areas, such as Los Angeles (177,000 tons), Washington (35,000 tons), and Denver (33,000 tons), have lower particulate emission rates due to the absence of heavy industry and the lack of coal combustion.

In cities with high particulate emissions, coal combustion and industrial processes are the primary sources. In Pittsburgh, for example, 73 percent of particulate emissions was attributable to coal combustion and 24 percent to industrial processes. In Chicago, 47 percent came from coal combustion and 46 percent from industrial processes.

In cities where emission surveys were recently conducted, nearly every coal-fired power plant was equipped with some sort of control device. This is essentially true also of the larger industrial process sources, such as cement plants and iron and steel mills. In contrast, the multitude of smaller sources, such as foundries, concrete batching plants, and grain storage and handling facilities, are for the most part uncontrolled.

From 1966 to 1968, the nationwide emission of particulate pollutants dropped about 300,000 tons, from 28.6 to 28.3 million tons. The changes, summarized in Table 6, that affected these rates are:

1. An increase in power plant use of coal but a counteracting increase in collection efficiency of control equipment. (New control equipment and phasing out of old boilers.)
2. A decrease in amount of coal burned by industry and other sources (residential, commercial, and institutional) for heat and power.
3. A decrease in emissions from transportation sources other than motor vehicles, especially railroads and vessels.

4. An increase in emissions from solid waste disposal practices.
5. A decrease in industrial process emissions. This is an apparent decrease only, since the differences are due to changes in emission factors and basic data.

Table 6. NATIONWIDE EMISSIONS OF PARTICULATES BY YEAR
(10⁶ tons)

Source	1966	1967	1968	Change from 1966 to 1968
Transportation	1.2	1.1	1.2	N ^a
Motor vehicles	0.7	0.7	0.8	+0.1
Other	0.5	0.4	0.4	-0.1
Fuel combustion	9.2	8.9	8.9	-0.3
Coal	8.5	8.2	8.2	-0.3
Fuel oil	0.3	0.3	0.3	N
Natural gas	0.1	0.2	0.2	+0.1
Wood	0.3	0.2	0.2	-0.1
Industrial processes	7.6	7.3	7.5	-0.1 ^b
Solid waste disposal	1.0	1.1	1.1	+0.1
Miscellaneous	9.6	9.6	9.6	N
Man-made	2.9	2.9	2.9	N
Forest fires	6.7	6.7	6.7	N
Total	28.6	28.0	28.3	-0.3

^aN = Negligible.

^bApparent change.

SULFUR OXIDES

In 1968, approximately 33.2 million tons of sulfur oxides, primarily SO₂, was emitted in the United States (Table 7). More than 24 million tons, or 74 percent of the national total, was produced by the burning of fuels. Coal combustion accounted for 20.1 million tons and fuel oil combustion for about 4.3 million tons. Power plants, of which there are approximately 940 in the country, emitted 16.8 million tons of sulfur oxides, and industrial plants emitted 5.1 million tons. The remaining 2.5 million tons was discharged by the space heating of homes and businesses.

Table 7. NATIONWIDE SULFUR OXIDES EMISSIONS, 1968

Source	Emissions, 10 ⁶ tons/yr	Percent of total
Transportation	0.8	2.4
Motor vehicles	0.3	0.9
Gasoline	0.2	0.6
Diesel	0.1	0.3
Aircraft	N ^a	N
Railroads	0.1	0.3
Vessels	0.3	0.9
Non-highway use of motor fuels	0.1	0.3
Fuel combustion in stationary sources	24.4	73.5
Coal	20.1	60.5
Distillate fuel oil	0.4	1.2
Residual fuel oil	3.9	11.8
Natural gas	N	N
Wood	N	N
Industrial processes	7.3	22.0
Solid waste disposal	0.1	0.3
Miscellaneous	0.6	1.8
Forest fires	N	N
Coal refuse	0.6	1.8
Total	33.2	100.0

^aN = Negligible.

Industrial processes added an additional 7.3 million tons annually to the nationwide emissions. Four industries collectively contributed most of this total: petroleum refineries (2.1 million tons), smelters (3.9 million tons), sulfuric acid manufacturing plants (0.6 million tons), and coking operations (0.6 million tons).

The remaining 1.5 million tons of sulfur oxides was emitted by the combustion of coal refuse banks (0.6 million tons), the combustion of fuels for transportation (0.8 million tons), and the disposal of solid wastes (0.1 million tons).

The majority of sulfur oxides emissions are concentrated in specific regions of the country. The seven industrial northeastern states, in which coal and residual fuel oil are important sources of heat and power, accounted for 16 million tons, or almost 50 percent of the national total. The only other states with estimated emissions of more than 1 million tons per year were Arizona and Texas. In these

two states, the primary sources are smelters and refineries, which collectively contributed in excess of 80 percent of each state's total.

From 1966 to 1968, emissions of sulfur oxides increased 2.3 million tons, an actual increase resulting from the following changes (shown in Tables 8 and 13):

1. A 2.4-million-ton increase from steam electric power plants due to increased coal and oil consumption.
2. A 0.5-million-ton decrease from industrial and residential fuel sources due mainly to decreased coal usage.
3. A 0.2-million-ton increase in industrial processes, such as petroleum refining, smelting, and sulfuric acid production.
4. A 0.2-million-ton actual increase in emissions from automobile and other transportation sources.
5. Increased sulfur content of coal due to exhaustion of sources of low-sulfur coal.

Table 8. NATIONWIDE EMISSIONS OF SULFUR OXIDES BY YEAR
(10⁶ tons)

Source	1966	1967	1968	Change from 1966 to 1968
Transportation	0.6	0.7	0.8	+0.2
Motor vehicles	0.2	0.3	0.3	+0.1
Other	0.4	0.4	0.5	+0.1
Fuel combustion	22.5	23.1	24.4	+1.9
Coal	18.7	19.1	20.1	+1.4
Fuel oil	3.8	4.0	4.3	+0.5
Natural gas	N ^a	N	N	N
Wood	N	N	N	N
Industrial processes	7.1	7.2	7.3	+0.2
Solid waste disposal	0.1	0.1	0.1	N
Miscellaneous	0.6	0.6	0.6	N
Man-made	0.6	0.6	0.6	N
Forest fires	N	N	N	N
Total	30.9	31.7	33.2	+2.3

^aN = Negligible.

All changes that occurred in sulfur oxides emissions are actual changes. The differences in emission rates, then, are due to natural increases or decreases in fuel consumption, motor vehicle travel, solid waste disposal, or industrial production.

About two-thirds of the nationwide emission of sulfur oxides occurs within urban areas. Power plants, industries, businesses, and homes all contribute to emissions in urban areas. Much of the pollution in rural areas is emitted by a relatively small number of large individual sources. Individual smelters, many of which are located away from metropolitan areas, may emit over 100,000 tons per year. In addition, almost half of the nation's 940 power plants, including seven of the eight largest SO₂ emitters, are located in rural areas. Annual emissions from these seven range from 200,000 to 300,000 tons per year.

HYDROCARBONS

In 1968, approximately 32 million tons of hydrocarbons (Table 9) was emitted in the United States. Of the sources surveyed, motor vehicles were the largest single emitters of HC, accounting for 15.6 million tons per year, or 52 percent of the total. Industrial process losses were the next largest source, accounting for 4.6 million tons.

Other sources, such as forest fires, organic solvent evaporation, fuel combustion in stationary sources, and disposal of solid wastes accounted for the majority of the remaining 11.8 million tons.

An estimated 19 million tons, or 60 percent of the national total, was emitted in urban areas. Motor vehicles accounted for 7 million tons of this total. Although vehicular travel will increase rapidly in the next few years, proposed control measures will significantly reduce the HC emissions (see Motor Vehicle Projections). The percentage reduction of HC emissions, however, will be greatest in rural areas because travel speeds, which are in inverse relation to HC emissions, are higher in rural areas.

Table 9. NATIONWIDE HYDROCARBON EMISSIONS, 1968

Source	Emissions, 10 ⁶ tons/yr	Percent of total
Transportation	16.6	51.9
Motor vehicles	15.6	48.8
Gasoline	15.2	47.5
Diesel	0.4	1.3
Aircraft	0.3	0.9
Railroads	0.3	0.9
Vessels	0.1	0.3
Non-highway use of motor fuels	0.3	1.0
Fuel combustion in stationary sources	0.7	2.2
Coal	0.2	0.6
Fuel oil	0.1	0.3
Natural gas	N ^a	N
Wood	0.4	1.3
Industrial processes	4.6	14.4
Solid waste disposal	1.6	5.0
Miscellaneous	8.5	26.5
Forest fires	2.2	6.9
Structural fires	0.1	0.3
Coal refuse burning	0.2	0.6
Agricultural burning	1.7	5.3
Organic solvent evaporation	3.1	9.7
Gasoline marketing	1.2	3.7
Total	32.0	100.0

^aN = Negligible.

From 1966 to 1968, there was an increased emission of 0.5 million tons of HC (Table 10). This was due to the following:

1. A 1-million-ton decrease in emissions from transportation sources. This is an actual decrease effected as the result of Federal exhaust emissions standards.
2. A 1.1-million-ton increase in industrial process emissions. This large increase was due in part to the inclusion of new industrial sources since the 1966 emission estimates were made and in part to natural increases in emissions from existing sources.
3. Natural increases in solid waste disposal emissions, gasoline marketing and handling, and solvent evaporation.

Table 10. NATIONWIDE EMISSIONS OF HYDROCARBONS BY YEAR
(10⁶ tons)

Source	1966	1967	1968	Change from 1966 to 1968
Transportation	17.6	17.3	16.6	-1.0
Motor vehicles	16.5	16.3	15.6	-0.9
Other	1.1	1.0	1.0	-0.1
Fuel combustion	0.7	0.7	0.7	N ^a
Coal	0.2	0.2	0.2	N
Fuel oil	0.1	0.1	0.1	N
Natural gas	N	N	N	N
Wood	0.4	0.4	0.4	N
Industrial processes	3.5	4.3	4.6	+1.1 ^b
Solid waste disposal	1.5	1.6	1.6	+0.1
Miscellaneous	8.2	8.3	8.5	+0.3
Man-made	6.0	6.1	6.3	+0.3
Forest fires	2.2	2.2	2.2	N
Total	31.5	32.2	32.0	+0.5

^aN = Negligible.

^bApparent change.

NITROGEN OXIDES

In 1968, about 21 million tons of NO_x was emitted in the United States (Table 11). Although basic data are not complete for 1970, emissions are thought to have increased to 23 million tons, a change primarily due to an increase of about 4 percent per year in emissions from motor vehicle exhausts and a slightly lower rate of increase for stationary combustion source emissions.

Motor vehicles and the burning of coal, oil, and natural gas are the principal sources of NO_x. In 1968, these sources accounted for over 18 million tons or almost 88 percent of the national total. Of the 10.0 million tons generated by the combustion of fuels, power plants emitted 4.0 million tons; industries, 4.8 million tons; and home and office heating, the remaining 1.2 million tons. Natural gas, the primary source, accounted for over 4.4 million tons. An estimated 8 million tons of NO_x was emitted by transportation sources, with 7 million tons of that coming from motor vehicles. Industrial processes, solid waste disposal, and other miscellaneous sources accounted for about 2.5 million tons of NO_x.

Table 11. NATIONWIDE NITROGEN OXIDES EMISSIONS, 1968

Source	Emissions, 10 ⁶ tons/yr	Percent of total
Transportation	8.1	39.3
Motor vehicles	7.2	34.9
Gasoline	6.6	32.0
Diesel	0.6	2.9
Aircraft	N ^a	N
Railroads	0.4	1.9
Vessels	0.2	1.0
Non-highway use of motor fuels	0.3	1.5
Fuel combustion in stationary sources	10.0	48.5
Coal	4.0	19.4
Fuel oil	1.0	4.8
Natural gas ^b	4.8	23.3
Wood	0.2	1.0
Industrial processes	0.2	1.0
Solid waste disposal	0.6	2.9
Miscellaneous	1.7	8.3
Forest fires	1.2	5.8
Structural fires	N	N
Coal refuse burning	0.2	1.0
Agricultural burning	0.3	1.5
Total	20.6	100.0

^aN = Negligible.

^bIncludes LPG and kerosene.

Nitrogen oxides and CO, probably more than other pollutants, are closely related to the distribution of population in the country since motor vehicles and all fuels—coal, fuel oil, natural gas, kerosene, and liquefied petroleum gas (LPG)—contribute significantly to total emissions. It is not surprising, therefore, that over 60 percent of NO_x emissions in the country occur in urban areas. In terms of sources, 45 percent of the NO_x emissions from motor vehicles are in urban areas because, unlike those of CO and HC, they are unaffected by travel speed. The percentage of vehicular emissions of NO_x in urban areas is relatively low.

Nitrogen oxides increased 3.9 million tons from 1966 to 1968 (Table 12), largely because of the following changes:

1. A 2.7-million-ton apparent increase from the burning

of natural gas. Most of this increase was due to the inclusion in the estimates of new sources such as gas transmission and gas pipelines.

2. A 0.5-million-ton actual increase in emissions from utilities, mainly from increased coal combustion.
3. A 0.5-million-ton increase in emissions from motor vehicles resulting from increased vehicular activity and an increased emission factor because of exhaust emission controls. This is an actual increase.

Table 12. NATIONWIDE EMISSIONS OF NITROGEN OXIDES BY YEAR
(10⁶ tons)

Source	1966	1967	1968	Change from 1966 to 1968
Transportation	7.6	7.6	8.1	+0.5
Motor vehicles	6.6	6.7	7.2	+0.5
Other	1.0	0.9	0.9	N ^a
Fuel combustion	6.7	9.5	10.0	+3.3
Coal	4.0	3.8	4.0	N
Fuel oil	0.9	1.0	1.0	+0.1
Natural gas	1.6	4.2	4.5	+2.9 ^b
Wood	0.2	0.2	0.2	N
LPG and kerosene		0.3	0.3	+0.3 ^b
Industrial processes	0.2	0.2	0.2	N
Solid waste disposal	0.5	0.6	0.6	+0.1
Miscellaneous	1.7	1.7	1.7	N
Man-made	0.5	0.5	0.5	N
Forest fires	1.2	1.2	1.2	N
Total	16.7	19.6	20.6	+3.9

^aN = Negligible.

^bApparent change.

FUEL EMISSIONS FROM STATIONARY SOURCES

Table 13 presents nationwide emissions from fuel combustion in stationary sources from 1966 through 1968.

Table 13. EMISSIONS FROM FUEL COMBUSTION BY STATIONARY SOURCES, 1966 THROUGH 1968
(10⁶ tons/year)

Source	Particulates	SO _x	NO _x
1966			
Utilities	5.6	14.4	3.5
Industrial	3.0	5.5	2.4
Residential-commercial	0.6	2.6	0.8
Total	9.2	22.5	6.7
1967			
Utilities	5.6	15.4	3.6
Industrial	2.7	5.1	5.0
Residential-commercial	0.6	2.6	0.9
Total	8.9	23.1	9.5
1968			
Utilities	5.6	16.8	4.0
Industrial	2.7	5.1	5.1
Residential-commercial	0.6	2.5	0.9
Total	8.9	24.4	10.0

Particulate emissions from steam-electric utilities have remained about constant during this time period. This is due to the increased efficiency of control equipment and the phasing out of older boilers. Emissions from industrial sources have declined because of a decrease in coal usage.

On the other hand, SO_x emissions from utilities have increased over 16 percent because of increased coal consumption compounded by higher coal sulfur content.

Nitrogen oxides emissions show a large jump from 1966 to 1968. This is due, however, to the inclusion of new sources such as natural gas transmission and natural gas pipelines, as well as the inclusion of other fuels, such as LPG and kerosene, and is, then, an apparent increase.

PROJECTIONS OF MOTOR VEHICLE EMISSIONS

The graphs given here present the automotive emissions of CO, HC, and NO_x projected to the year 1990 and are based on emission regulations presently in force and those forthcoming in 1970 and 1971. Only gasoline-powered vehicles are included in the projections since they account for more than 95 percent of the vehicular emissions of these pollutants.

The vehicular travel data used were extracted from projections, presented in Landsberg's Resources in America's Future,¹ that were made by Resources for the Future, a nonprofit research foundation affiliated with Johns Hopkins University. These projections have been widely accepted and are frequently used in studies concerned with natural resources and environmental pollution. Completed in 1963, the projections are of three separate levels (high, medium, and low) of expected motor vehicle travel in the United States. Actual data for the past 5 years reflect a rate of increase in travel close to the medium projections. Computations, therefore, are based on the expectation that future increases will continue along these lines. The projected emission levels are presented in Figures 1 through 3.

Carbon monoxide emissions are estimated to have reached a peak during the calendar year 1967. The 1968 enactment of Federal standards should produce a steady decrease in emissions that will persist until about 1980, when increases in motor vehicle travel will counteract the effects of the controls and an upward trend can again be anticipated. It is anticipated that emissions in urban areas, although expected to follow the same general trend, will increase at a somewhat faster rate than total nationwide emissions.

Hydrocarbon emissions display a trend similar to that shown by CO. The 1963 crankcase control device decelerated the rate of increase

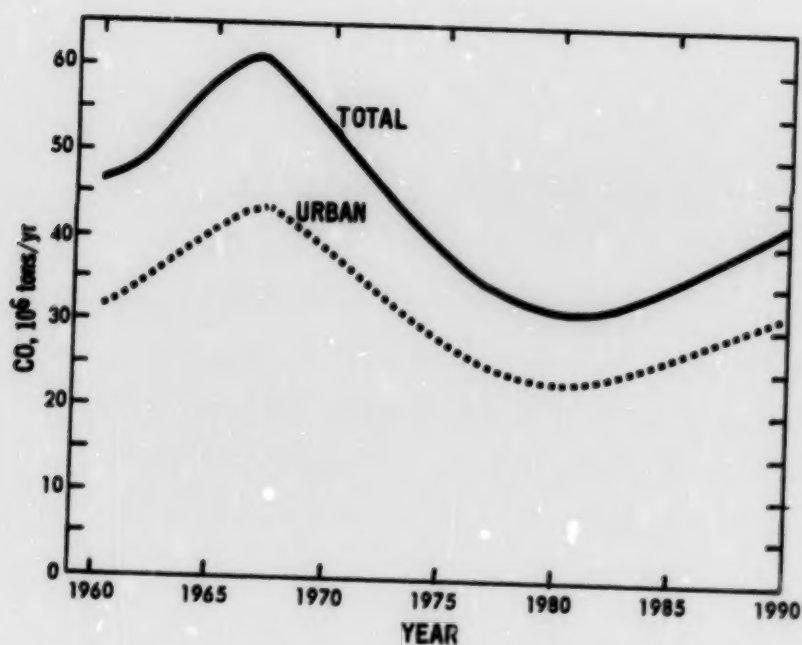


Figure 1. Carbon monoxide emission estimates based on present legislative standards.

Figure 2. Hydrocarbon emission estimates based on present legislative standards.

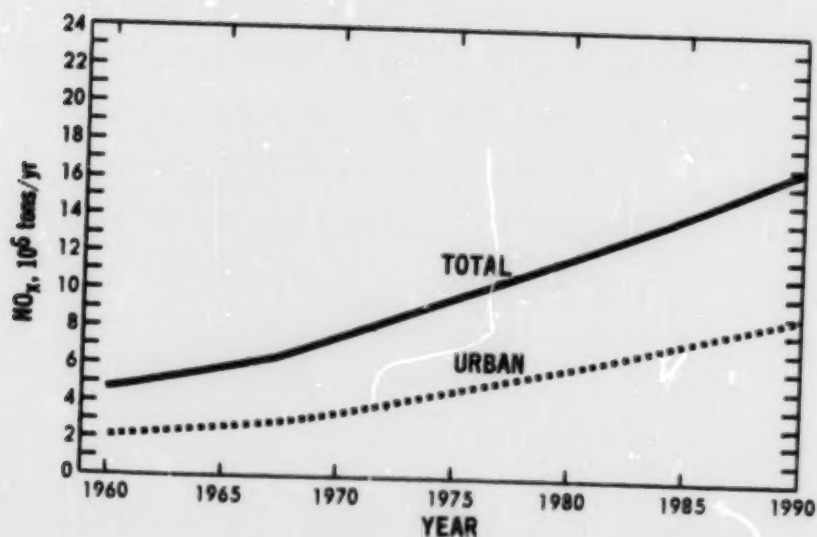
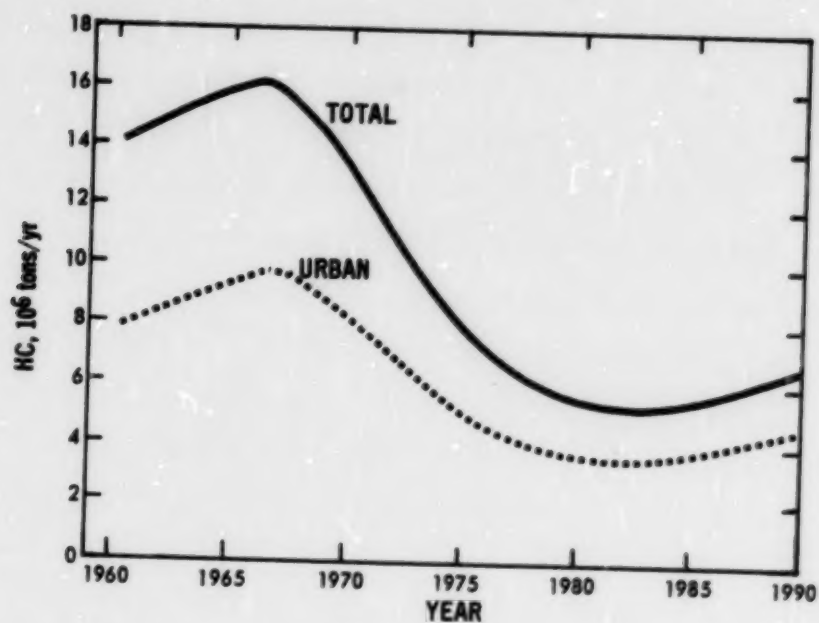


Figure 3. Nitrogen oxides emission estimates based on present legislative standards.

of emissions even though the magnitude of emissions increased. Peak emissions occurred in 1967. Subsequent exhaust and evaporation controls will reduce emissions to a minimum in 1983 (5.24 million tons) before they begin to increase once again.

Because of lack of controls, NO_x emissions are estimated to increase at the same rate as motor vehicular travel. Figure 3 presents NO_x emissions based on no controls. There is an obvious change in the slope of the curve for the year 1968 because of exhaust emission controls that increased the NO_x emission rate.

METHODOLOGY

Basically, the emission estimates for any given year were derived by multiplying the projected annual vehicle miles of travel (by type and age of vehicle and driving conditions) by the appropriate emission factor (grams per vehicle-mile).

Separate travel data were developed for urban and rural driving for automobiles and light- and heavy-duty trucks. Data on the distribution by age of the vehicles were also developed. By using the above categories of data, factors such as driving speeds, amount of exhaust, and the deterioration of control devices—all of which affect the emission rate from individual vehicles—could also be considered.

Emission factors were developed from cycle data. Conversion factors developed from road data were used to relate cycle-based emissions to on-the-road vehicle estimates. Emission factors used in making these projections reflect the variations that result from type and age of vehicles, vehicle speed, type of transmission, and control devices.

MOTOR VEHICLES

Emission estimates from gasoline-powered motor vehicles were obtained by two basic approaches, both of which were necessary since complete lists of emission factors were not available for SO_x and particulates as they were for CO, HC, and NO_x .

Estimates of CO, HC, and NO_x were based upon vehicle-mile tabulations and emission factors developed from both road and cycle data.² The distribution of vehicle miles by vehicle type and location is presented in Table 14. The emission factors used account for variations in emissions due to type, speed, age, transmission, size of engine, and size of vehicle.

Estimates of SO_x and particulate emissions were based on the consumption of 75,500 million gallons of gasoline.³ An average particulate

Table 14. VEHICLE TRAVEL IN UNITED STATES, 1968
(10⁹ miles)

Vehicle	Urban	Rural	Total	
			1968	1966
Passenger cars	409.02	374.56	783.58	744.80
Light-duty trucks	32.42	48.63	81.05	80.63
Heavy-duty trucks				
Class II	9.06	13.58	22.64	22.52
Class III	6.03	9.06	15.09	14.01
Class IV ^a				
Gasoline	11.36	27.81	39.17	38.97
Diesel	7.80	19.50	27.30	21.63
Total	475.69	493.14	968.83	922.56

^aIncludes buses.

emission factor and an average sulfur content of gasoline of 0.035 percent were applied to the gallonage.⁴ The average emission factors used to obtain estimates in this report are taken from Duprey.⁵

Emissions from diesel-powered motor vehicles were also based on fuel consumption data because of a lack of road-emission data. Average factors were applied to the 5,350 million gallons of diesel fuel consumed by motor vehicles.⁶

AIRCRAFT

The emissions in this category were determined from the results of an extensive study just completed for NAPCA.⁷ Estimates of all pollutants, except sulfur oxides, were presented for emissions at altitudes below 3,000 feet based on the number of flights made by different types of aircraft. Sulfur oxides emissions were calculated on the basis that aircraft fuels contain an average of 0.055 percent sulfur and that about 20 percent of the total fuel is consumed at altitudes below 3,000 feet.

RAILROADS

The 1968 fuel consumption by railroads was 3,530 million gallons of diesel fuel, 180 million gallons of residual fuel oil, and 100 million gallons of distillate fuel oil.⁸ The average emission factors, except those for SO_x, applicable to diesel fuel combustion were assumed to be

applicable also to residual and distillate fuel oils. The average sulfur content of each fuel was used in estimating SO_x emissions.

VESSELS

Ships and vessels consumed 766 million gallons of diesel fuels, 3,690 million gallons of residual fuel oil, 200 million gallons of gasoline, and 400 thousand tons of coal.^{8,9} These figures represent quantities sold in this country rather than quantities consumed, so that the fuels actually consumed within the country should be considerably less. Although emission factors are not available for this category, average emission factors applicable to other types of combustion were applied in order to obtain a gross estimate.

NON-HIGHWAY USE OF MOTOR FUELS

The non-highway consumption of motor fuels was 2.3 billion gallons of gasoline and 2.08 billion gallons of diesel fuel.⁴ Average emission factors for gasoline and diesel fuel combustion were used. Fuel consumption in the aviation and marine categories was excluded from this section since these sources were included in previous sections.

FUEL COMBUSTION IN STATIONARY SOURCES

COAL

Approximately 498 million tons of bituminous coal and lignite and 11 million tons of anthracite coal were consumed in the United States (excluding that consumed by railroads, ships, and vessels).⁹ Consumption by user category is summarized in Table 15. Average emission factors and the sulfur content of fuels for each category were used to estimate emissions. It was assumed that 79 percent of the particulate emissions from electric generating plants and 62 percent from industrial sources were collected.

Table 15. FUEL CONSUMPTION BY STATIONARY SOURCES, 1968

Source	Coal, 10 ⁶ tons/yr	Fuel oil, 10 ⁶ bbl/yr		Total gas, 10 ⁹ ft ³ /yr
		Residual	Distillate	
Electric utilities	297.1	185.0	3.0	3.144
Coke plants	91.3	-	-	-
Steel and rolling mills	5.7	-	-	-
Cement mills	9.4	-	-	-
Oil companies, gas pipelines, and gas transmission	-	39.3	9.4	3.720
Other manufacturing	82.6	135.7	45.8	7.030
Military	-	35.0	12.6	-
Residential, commercial, institutional, and light industrial	22.9	182.7	523.3	6.525 ^a
Total	509.0	577.7	594.1	20.419

^aDoes not include light industrial sources.

FUEL OIL

Approximately 594 million barrels of distillate fuel oil and 577 million barrels of residual fuel oil were consumed by stationary fuel combustion sources in 1968.⁸ Consumption by user category is sum-

marized in Table 15. Average emission factors and the sulfur content of fuels for each category were used to estimate emissions. It was assumed that there are no SO_x controls on fuel oil combustion sources.

NATURAL GAS

Total gas consumption, 99 percent of which consists of natural gas, exceeded 20.0 trillion cubic feet as shown in Table 15.¹⁰ Average emission factors and the sulfur content of fuels were used to estimate emissions.

WOOD

Total wood consumption by user category was not available; however, the total energy produced by wood combustion was approximately 780×10^{12} Btu for 1968.¹¹ Assuming 9,000 Btu per pound of wood, nearly 4.4×10^7 tons of wood was consumed. Average emission factors were used to estimate total emissions.

Table 16 provides the basic data used to calculate the 1966 emission estimates. It is presented here mainly for purposes of comparison.

Table 16. FUEL CONSUMPTION BY STATIONARY SOURCES, 1966

Source	Coal, 10 ⁶ tons/yr	Fuel oil, 10 ⁶ bbl/yr		Total gas, 10 ⁹ ft ³ /yr
		Residual	Distillate	
Electric utilities	266.4	140.7	3.6	2,610
Coke plants	96.4	-	-	-
Steel and rolling mills	8.0	-	-	-
Cement mills	9.3	-	-	-
Oil companies	-	35.2	10.5	-
Other manufacturing	91.0	141.1	47.1	6,630
Military	-	41.9	16.3	-
Residential, commercial, institutional, and light industrial	25.6	177.8	490.7	5,760 ^a
Total	497.0	536.7	568.2	15,000

^aDoes not include light industrial sources.

INDUSTRIAL PROCESSES

Certain industrial processes generate and emit varying quantities of pollutants into the air in addition to those produced by fuel combustion. The lack of published national data on production, type of equipment, and controls, as well as emission factors, makes it impossible to include estimates of emissions from all industrial process sources. This type of data is especially lacking with respect to hydrocarbons because the multitude of emission sources and the lack of data combine to prohibit the estimation of emissions from all but a few sources.

Table 17 summarizes the annual production of the various industrial processes surveyed. Also indicated are the sources for which emission estimates were made and those sources that are probably significant but for which no quantitative estimates could be made. In all cases, average emission factors were applied to total production numbers, when they were available, to obtain emissions. Various degrees of control were assumed.

Table 17. INDUSTRIAL PROCESS PRODUCTION, 1968

Source	Production, 10 ³ tons (except as noted) ¹²	CO	Particulates	SO _x	HC	NO _x
Iron and steel mills	134.000	u ^a	e ^b			
Coke manufacture	65.000	e	e		e	
Grey-iron foundries	22.000	e	e			
Aluminum primary	3.255					
Copper primary	1.440	u	e	e		
Lead primary	467		e	e		
Zinc primary	1.100		e	e		
Miscellaneous secondary metals	2.300		e	e		
Petroleum refineries	3.700 x 10 ⁶ bbl	e	e	e	e	e
Cement	403.000 x 10 ³ bbl		e			
Acid manufacture						
Phosphoric	4.500		e			
Nitric	6.100		e			e
Sulfuric	28.400		e	e		e
Hydrochloric	1.700		u			
Mineral industries	2.650.000		e			
Explosives	-		u			u
Petrochemicals	-					
Cotton	11 x 10 ⁶ bales				e	
Pulp mills, Kraft and neutral sulfite semichemical (NSSC)	28.100	e	e	e		
Grain handling	530.000		e			
Grain milling	160.000		e			

^au = Emissions probably large but not estimated.

^be = Emissions estimated.

SOLID WASTE DISPOSAL

A study on solid waste collection and disposal practices has recently been completed by the Bureau of Solid Waste Management of the U.S. Department of Health, Education, and Welfare.¹³ Results indicate that the average collection rate of solid waste is about 5.5 pounds per capita per day in the United States. It has been estimated that a conservative estimate of the total generation rate is 10 pounds per capita per day.

The results of this survey and the various assumptions necessary have been compiled to show the estimated distribution of solid waste disposal practices in Table 18. Average emission factors were applied to these totals to obtain estimates of total emissions from the disposal of solid wastes.

Table 18. SOLID WASTE DISPOSAL, 1966 AND 1968

Disposal method	Waste, 10 ⁶ tons/yr	
	1966	1968
Municipal incineration	16	19
On-site incineration	57	55
Sanitary landfills	10	29
Open dumps	227	218
Burned	77	82
Non-burned	151	136
Wigwam burners	27	27
Hog feeding	1	1
Composting, treatment plants, etc.	19	18
Total	358	367

MISCELLANEOUS SOURCES

FOREST FIRES

The United States Forest Service has provided information on the number of wild fires and the amount of controlled burning that occur in the United States. These data indicate that about 4.57 million acres (representing 145.6 million tons of combustible materials) of uncontrolled fires and 3.52 million acres (representing 76.4 million tons of combustible materials) of controlled fires occurred in 1966. Average emission factors were applied to these totals.

STRUCTURAL FIRES

Approximately one million buildings were attacked by fires in the United States. By using various assumptions, the amount of combustibles and average emission factors were estimated and a rough approximation of emissions was obtained.

COAL REFUSE BURNING

It is estimated that 19 billion cubic feet of burning coal refuse piles existed in the United States in 1964. By using assumed densities and average lives for coal piles, a rough estimate of emissions was obtained.

ORGANIC SOLVENT EVAPORATION

Insufficient national data were available to permit the estimation of hydrocarbon emissions from organic solvent evaporation. A rough estimate of nationwide emissions was made from the extrapolation, on a national scale, of data gathered in four metropolitan areas: Los Angeles, San Francisco, St. Louis, and Washington, D. C. Due to the nature of these urban areas, the nationwide totals arrived at may be high. One-third of the total HC emissions is attributed to evaporation from the solvents handled by the paint and varnish industry, for which estimates of gallonage and resultant emissions were available.

GASOLINE MARKETING

The evaporation of motor fuels during the filling of tank trucks, service station tanks, and automobile tanks is included in this section. Other sources are the evaporation of gasoline from storage tanks at refineries and bulk terminals and evaporation during the operation of motor vehicles. These emissions were included in the petroleum refinery and motor vehicle sections. Average evaporation factors were applied to the amount of gasoline and diesel fuel consumed in order to estimate HC emissions from gasoline marketing.

AGRICULTURAL BURNING

Nearly 280 million tons of agricultural refuse is burned annually in the United States. This includes crop residues, scrub, brush, weeds, grass, and other vegetation.

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